

# **Swash Zone Morphodynamics on a Steep, High Energy Beach**

Mark Merrifield  
Department of Oceanography  
University of Hawaii at Manoa  
1000 Pope Rd., MSB 317  
Honolulu, HI 96816-2336

phone: (808) 956-6161 fax: (808) 956-2352 email: markm@soest.hawaii.edu  
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## **LONG-TERM GOALS**

The long-term goal of this program is to understand the processes that determine the erosion/accretion rates and patterns on a steep, porous beach face for a wide range of incident wave conditions.

## **OBJECTIVES**

The objective of this project is to relate incident wave conditions and the resulting foreshore morphology response at Waimea Bay, a steep pocket beach on the north shore of Oahu, Hawaii. The run-up variability, characterized using Argus video imagery, will be compared to offshore and breaking wave heights. The resulting picture of incident wave forcing will be related to three-dimensional morphology changes determined using high resolution RTK-GPS (Real-Time Kinematic GPS) surveys. The results from this high energy, reflective beach will then be compared with observations from more dissipative beaches. We seek to determine whether characteristic beach parameters are useful for categorizing and understanding swash zone morphodynamics for high energy environments.

## **APPROACH**

Although the offshore wave conditions and video images of morphology changes at Waimea Bay have been under study for several years, a more intensive effort was focused over March 1996 to July 1997 to obtain quantitative results over a full seasonal cycle. During this period high resolution (4 m horizontal, 2-5 cm vertical accuracy) surveys of the sub-aerial beach were made every 1-2 weeks using RTK-GPS technology. With this method, the entire beach can be sampled in approximately 3-4 hours (~1200 data points). In order to quantify erosional as well as accretional events, our strategy has been to map the beach before and after energetic swell events and also during lower wave energy accretional phases.

The wave forcing at Waimea Bay has been specified using a combination of data sources. Hourly measurements of the offshore wave field in the Hawaii region were obtained from NOAA directional (51026) and non-directional (51001) wave buoys located 122 and 474 km from Waimea Bay. To supplement the buoy data, daily visual observations of breaking wave heights at Waimea Bay and, on lower energy days, at nearby Sunset Beach were recorded. Run-up variability at the site also was monitored daily using the Argus video system [Holland et al, 1997]. After digitizing the run-up images and converting the resulting 18 minute time series to vertical run-up excursions, the run-up magnitudes and frequency spectra were calculated.

The RTK-GPS equipment and GPS expertise were provided by the Pacific GPS Facility headed by Dr. Michael Bevis, University of Hawaii at Manoa. The buoy data records and

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database of daily visual observations were made available through Pat Caldwell, Joint Institute of Marine Research and the National Ocean Data Center. The Argus video system data was provided by Dr. Rob Holman, Oregon State University.

## **WORK COMPLETED**

During the one-year study period, 32 RTK-GPS surveys of the site were completed. Various error analysis methods allowed easy identification of potential problems and indicated the method was accurate (2-5 cm vertical) and repeatable. Several surveys were excluded from the analysis: three were of poor quality (high error values or sparse sampling) and in two others the morphology was primarily controlled by run-off during a severe rain storm (a non-marine effect). The survey data were gridded using a standard tessellation method to allow for plotting and comparison (see example in Fig. 2A). Net sand volume changes and cross-shore sand flux rates have been computed for consecutive maps (Fig. 1C) and spatial variability has been characterized using empirical orthogonal eigenfunctions (EOFs). In all occurrences of newly formed cusped features (14 observations), the average cusp length, depth, and location were determined and tabulated.

The wave climate records have been processed and show good correlation between measurement methods. Run-up records were processed on a daily basis during the winter season, and every 1-3 days during the summer season for a total of 240 run-up records. Infragravity (0.004 to 0.04 Hz) and swell (0.04 to 0.30 Hz) frequency band energies have been calculated for all records. The vertical run-up excursions correlate well with both the offshore wave records (correlation of 0.75), and with the breaking wave height records (correlation of 0.88). The breaking wave height time series is shown in Fig. 1A with survey times indicated by the diamonds. The wave power ( $H_o^2T$ ) time series is also provided in Fig. 1B.

A poster presentation, entitled "Morphology Changes on a Steep, High Energy Beach", describing preliminary results and analysis of this study, was presented at the Fall 1996 AGU meeting. An oral presentation at the 1997 GSA meeting (Cordilleran Section), entitled "Waimea Bay Shoreline Changes: Trends Versus Natural Variability", detailed the application of beach morphology data to shoreline measurement variability estimates for studies of long term (decadal) shoreline change at Waimea.

## **RESULTS**

Temporal and spatial scales of foreshore response to a wide variety of incident wave conditions have been quantified. The primary results to date are:

- 1) The rates of beach erosion and recovery were rapid, even under typical wave conditions for the site. Figure 1C shows cross-shore sediment flux rates between surveys. Maximum erosion/accretion rates of  $-8/+4 \text{ m}^3/\text{m day}$  were observed for durations of 12/10 days straight. The three-dimensional change maps shown in figures 2B and 2C reveal extensive longshore variability in erosion/accretion patterns. The erosional event (Fig. 2B) involved intense wave energy (breaking wave heights of 6 m) which formed large scale cusps (~70 m) due primarily to removal of sediment from the embayments but also by some buildup at the cusp horns. The accretional map (Fig. 2C) reveals the rapid buildup (up to 3 m vertical change over 8 days) of a foreshore berm on one side of the beach and little change on the other.

- 2) A variety of morphodynamic parameterizations (e.g., Irribarren number) have been evaluated as indicators of the magnitude of foreshore erosion and accretion (quantified as sediment flux in Fig. 1C). The best correlation to date (0.5) has been for wave power

(Fig. 1B), however, work is still in progress and it is hoped that other parameterizations will prove more useful. As described for other sites [Wright, 1979], the beach state or profile type appears to be an important predictor of resistance or affinity to erosion and accretion. This important effect on beach change is not taken into account in most beach parameterizations and may have to be accounted for to obtain better correlations.

3) Work has been initiated to investigate cusp formation and morphology, with particular emphasis on the variability of infragravity / swell band energies determined from the run-up records. Cusp dimensions (14 independent sets of cusps) ranged from 30-70 m in length and 0.3-1.5 m in depth. The ratio of infragravity band energy (0.004 to 0.04 Hz) to total run-up energy averaged 0.15 for winter conditions and 0.06 for summer conditions. Run-up characteristics (peak infragravity and swell frequencies in particular) will be further investigated for cusp formation periods.

## **IMPACTS / APPLICATIONS**

Our application of RTK-GPS surveying techniques proved successful: the method was accurate, repeatable, and relatively simple. This project has successfully extended previous work [Morton et al., 1993], which compared the accuracy of various survey methods in a two day study, to a long term morphology study of a beach environment using RTK-GPS.

## **TRANSITIONS**

The data acquired during this project provides understanding of a little studied end of the morphodynamic spectrum. The data have been used to test existing beach parameterizations, and will be used in the future to test and extend existing foreshore sediment transport models for beach prediction purposes. The data will also provide shoreline variability estimates for long term shoreline change studies.

## **RELATED PROJECTS**

As results from the Duck, 97 field experiments become available, we intend to compare the behavior of Waimea Bay with similar run-up and beach morphology studies at Duck and Agate Beach, Oregon.

## **REFERENCES**

- Holland, K.T., R.A. Holman, T.C. Lippmann, J. Stanley, and N. Plant, Practical use of video imagery in nearshore oceanographic field studies, *IEEE Journal of Oceanic Engineering*, 22, 81-92, 1997.
- Morton, R.A., M.P. Leach, J.G. Paine, and M.A. Cardoza, Monitoring beach changes using GPS surveying techniques, *Journal of Coastal Research*, 9, 702-720, 1993.
- Wright, L.D., J. Chappell, B.G. Thom, M.P. Bradshaw, and P. Cowell, Morphodynamics of reflective and dissipative beach and inshore systems: Southeastern Australia, *Marine Geology*, 32, 105-140, 1979.